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A Novel Ranging Method Based on RSSI

Huanhuan Wang[a*], Jianchen Wan[a], Ruyou Liu[b]

[a] *The School of Information and Engineering, Huanghe Science and Technology College, Zhengzhou 450006, China*
[b]*The China Northeast General Municipal Engineering Design and Research Institute, Changchun, 130021 China*

Abstract

The ranging technique based on RSSI is often used in localization of wireless sensor network (WSN). Due to external interferences, the RSSI fluctuates a lot and then a novel ranging method is presented. It establishes a database of mapping relationship between the RSSI and the distance range, then the distance between the transmitter and the receiver can be drawn by summing weighted of the distance spaces obtained through querying the mapping database. Simulation results show that,this method can eliminate the negative effects on RSSI fluctuation as much as possible and provides high ranging precision. It's no environmental limitations and can be applied in range-based localization technique with high value.

Keywords: Accuracy, distance range, mapping relationship, ranging error, RSSI

1. Introduction

Node location information is the foundation and one of the core to study the technologies and applications of wireless sensor network (WSN) [1]. Generally, the localization algorithms can be classified into two categories: the range-based localization and the range-free localization [2]. For its high precise, the range-based localization algorithms have been widely applied. There are four generally accepted ranging methods. They are time of arrival, TOA [3], angle of arrival, AOA [4], time difference of arrival, TDOA [5] and received signal strength indicator, RSSI [6]. Each has its own advantages and disadvantages. It is arguable that RSSI provides the lowest cost technology as no special hardware is needed, such as in TOA, AOA, and TDOA, therefore RSSI is the method which the localization technology in WSN often uses. RSSI is usually regarded as one kind of rough ranging technique.Reflection, multipath propagation, NLOS propagation, antenna gain and other issues will be significant for the same distance of propagation loss. How to improve the accuracy of RSSI-based

* Corresponding author. Tel.: +86-15093327807.
E-mail address: whhnjdn@sina.com.

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ranging is a more meaningful question.

There exist many localization algorithms in the current literatures. Two main methods are used. One is through the acquisition of a large number of experimental data, it uses the propagation model to obtain the relational curve between the RSSI value and the distance [7]-[10]. The other is a map based approach, RSSI is measured to a set of references and a unique map is generated based around a probability distribution [11]. Using some previous knowledge of environment, maps can be tessellated together. Then in the actual range process, the RSSI measurement value is used to study the above relational curve or the map, the distance between the transmitter and the receiver can be drawn. The above mapping relations are the point-to-point mapping. However, due to environmental factors, there will be reflection, diffraction and diffraction phenomena in the actual process of the electromagnetic wave propagation. They make the RSSI value change greatly. Therefore, the above methods established the point-to-point relationship between the RSSI and the distance exist larger error. In the follow-up localization process refinement by several times is needed to improve the location accuracy, then the computation and communication overhead will greatly increase.

In this paper, after a thorough research on RSSI-based ranging method, we propose a new RSSI ranging method, it establishes a database of mapping relationship between the RSSI and the distance range. Because of this mapping is one to many mapping, it has a very good account of the instability of the RSSI value arose from outside interference, so it has smaller error. Simulation results show that the method has a high ranging accuracy.

2. Prerequisites

2.1. Select the appropriate transmit power

Transmit power determines the coverage of radio waves. For the transmit power adjustable transmitter, the maxi- mum transmit power may be used for long-distance communications, but differences in the RSSI are hardly visible for small distances between transmitters and receivers. However, for small areas, the short distance measurement for some applications is very important. So the transmit power must be well-controlled for meaningful RSSI-based distance measurements. We can do experi- ments in each mode of transmission power, respectively, measure large amounts of data, analysis of the curve of RSSI with distance under each transmit power, consider the volatility of changes in RSSI with distance, energy consumption, communication range and other factors, then select the most appropriate transmit power to ensure that the follow-up ranging error can be minimized.

2.2. Preferred RSSI measurement

Studies have shown that [12], in particular under the RSSI value from the distribution is a probability, the largest local density measurement and the true value is the closest place. Fitting the data, we found that the RSSI value under a certain distance meets the Gaussian distribution, the distribution density function:

$$f(x) = \frac{1}{\sqrt{2\pi} \cdot \sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{1}$$

in which,

$$\mu = \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

$$\sigma^2 = \frac{\sum_{i=1}^{n}(X_i - m)^2}{n-1} \quad (3)$$

X_i is for the ith signal RSSI value.

For this reason, we can do Gaussian fitting of the data, using equation (1), find the distribution density of the data, filter out most of the erroneous data. Then substitute the RSSI value into (1), when $0.5 \le f(x) \le 1$, we consider it is a large probability event and can be reserved. In this way the current situation can be optimized, thereby it can reduce some of the small probability of large interference measurements on the overall impact of the event, so that it has a certain improvement on ranging error.

3. Ranging Model

3.1. Establish the mapping relationship between the distance and RSSI range

By preferring the RSSI value for each distance, we can establish the mapping relationship between a certain distance and the RSSI range under that distance. For illustrative purposes, we make the following definition: d_i expresses a certain distance, $i = 1, 2, \cdots, n$; R_i expresses the effective RSSI set in a certain distance; $RSSI_{ij}$ expresses the elements of the ith set. Among them, the range of n values are based on distance and experimental step to determine; due to the difference of the number of useful RSSI under a certain distance, therefore j varies according to the set of R_i. Thus, the mapping relationship between the distance and RSSI range may be represented as:

$$d_i \sim R_i \quad (4)$$

3.2. Establish the mapping relationship between RSSI and the distance range

If the RSSI value with a corresponding distance is listed, it will not be one to one relationship. Studies have shown that [12], each RSSI value corresponds to a distance rang, intensity range of the values appears small, low-intensity range of values occurs. Based on this, if we separately find all the distances that each different RSSI value corresponds to in each set R_i, the mapping relationship above can be exchanged, that is to say, we can establish the mapping relationship between RSSI and the distance range. Defined D_i as a set of values corresponding to the distance and d_i as the elements in which, then the mapping relationship between RSSI and the distance range can be expressed as:

$$RSSI_i \sim D_i \quad (5)$$

The mapping database can be as distance required. As a result, the mapping between RSSI value and the distance is no longer one-to-one relationship, but one RSSI value corresponds to a distance range, so it can minimize the negative impact of RSSI fluctuation as much as possible.

3.3. Calculate the distance

In the course of the actual distance, we used the receiver to request k data packets with arbitrary distance and saved the respective RSSI values, some of the RSSI value may be the same. Suppose there has m ($m \le k$) different RSSI value in the k data, which is separately expressed by $RSSI_j$, in which $j = 1,2,\cdots,m$. The number which each $RSSI_j$ present is separately expressed by x_j , then

$x_1 + x_2 + \cdots + x_n = k$.

For the mapping relationship $RSSI_i \sim D_i$ the m RSSI form the input and the associated distance range the output, then we can get m different distance ranges and is separately expressed by D_j , in which $j = 1,2,\cdots,m$. $d_{j\min}$ expresses the minimum element of the j-th distance range D_j and $d_{j\max}$ expresses the maximum element. We deal with the m ranges by separately summing weighted of the minimum and the maximum of each range, and the weight of each range is the number each $RSSI_j$ present, then a new distance range can be obtained, the minimum and the maximum of which is in following:

$$d_{\min} = \frac{\sum_{j=1}^{m} x_j \cdot d_{j\min}}{k} \qquad d_{\max} = \frac{\sum_{j=1}^{m} x_j \cdot d_{j\max}}{k} \tag{6}$$

Take the centroid of the new range for the transmitter, the distance between the transmitter and receiver is :

$$d = \frac{d_{\min} + d_{\max}}{2} \tag{7}$$

4. Simulation

In this section we present a complete performance evaluation of the range method presented using simulations. Simulation code is executed from the MATLAB environment.

4.1. Setting the scene

The transmitter drove over a distance of 30m in steps of

50cm toward the receiver, simultaneously added the Gauss random noise. At each step, the receiver requested 20000 packets and preferred the 20000 RSSI values, respectively. Then according to previously described scenarios ranging principle, we can establish the relational database between RSSI and the distance range.

Under the same conditions we redone the experiment, in this experiment 10 packets are needed at each step. We counted different RSSI values in the 10 packets and the respective number of occurrences, they are used to study the mapping database, then we can obtain some distance ranges. By summing weighted of these distance ranges, the measurement of each step can be drawn.

4.2. Simulation Results

To validate the performance of proposed ranging method, we compared the method with the traditional method using fitting curve. Table 1 shows the ranging results of the two methods under he same conditions. As can be seen from the data in the table, the proposed ranging method within 10 meters, ranging error not exceeding 0.5 m; within 20 meters range, range error of less than 1 m; within 30 meters , the error does not exceed 2 meters.

Table 1. Ranging results

Actual distance	New method Estimated distance	New method Error	Traditional method Estimated distance	Traditional method Error
2	2	0	2.2167	0.2167
3	3	0	6.5388	3.5388
4	3.925	0.075	2.8979	1.1021
5	5	0	2.5419	2.4581
6	6.15	0.15	5.9861	0.0139
7	7.025	0.025	8.4128	1.4128
8	7.95	0.05	10.0541	2.0541
9	8.75	0.25	10.7824	1.7824
10	10.125	0.125	11.4068	1.4068
11	11.175	0.175	11.703	0.703
12	12.475	0.475	12.0982	0.0982
13	12.85	0.15	12.2734	0.7266
14	13.95	0.05	12.8603	1.1397
15	14.35	0.65	13.0347	1.9653
16	16.15	0.15	14.4396	1.5604
17	17.025	0.025	15.1913	1.8087
18	18	0	16.2989	1.7011
19	19.05	0.05	17.3398	1.6602
20	19.55	0.45	17.9263	2.0737
21	21.5	0.5	20.2039	0.7961
22	22.5	0.5	21.5058	0.4942
23	23.45	0.45	22.6853	0.3147
24	25	1	24.5867	0.5867
25	25.15	0.15	24.7432	0.2568
26	26.825	0.825	26.9196	0.9196
27	26.725	0.275	26.7425	0.2575
28	27.725	0.275	28.0174	0.0174
29	30.175	1.175	30.8266	1.8266
30	29.55	0.45	30.1943	0.1943

Fig. 1 shows rang error using the new method and the traditional, respectively. Obviously, under the same condition, the method proposed in this paper has the small range error compared to the tradition RSSI-based range method and the range precision is higher. In addition, the range error of the new method increases along with the distanceincreases.

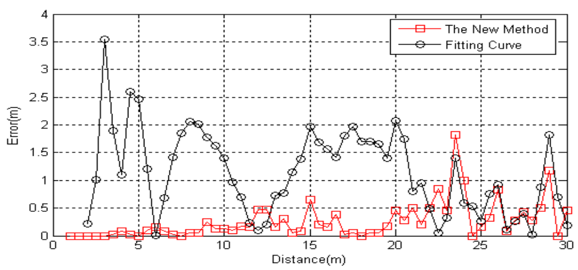

Fig. 1.The curve of rang error

5. Conclusion

The RSSI-based ranging method will have a greater impact of ranging error because the influence of external environment. In this paper, we present a novel RSSI-based ranging method. It's mapping relationship between RSSI and distance range reduces the negative effects on RSSI fluctuation as much as possible. When compared to the method of using fitting curve, our method performs better. Meanwhile, it is no environmental limitations, simply create a particular context of the mapping database, you can achieve the precise range of the scenarios. It can be applied in range-based localization technique with high value.

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